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Original Article

Morphological and Zoometrical Indices for Assessing Ethnological and Functional Traits in Red Sokoto Does and Other Nigerian Indigenous Goat Populations

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[1] Suleiman, I. O., *[1]Abubakar, A. S. & [2] Durodola, H.

[1]Department of Animal Science, Bayero University, Kano
[2]Duha Farms and Agricultural Consultancy Services, Abuja
**ahmadsalimabubakar@gmail.com; 08069083991*

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Abstract

This study assessed morphological and zoometrical traits of Red Sokoto does within Kano metropolis and compared them with Sahel goats across Nigeria. Forty-seven Red Sokoto does were evaluated using twelve linear body measurements to derive key morpho-functional indices. Heart girth showed a strong positive correlation with body weight, supporting its use for field weight prediction. Conformation and Compactness Indices increased significantly with age and parity, reflecting enhanced functional traits in mature, multiparous does. Most indices showed low variation, indicating genetic stability, while moderate variability in Body Length Index suggested potential for selection. A broader comparison with Sahel goats (n = 100) revealed significant inter-breed differences, particularly in pelvic structure. Overall, Nigerian indigenous goats were medium-sized with meat-type conformations. These results highlight the genetic diversity and structural soundness of Red Sokoto goats, providing valuable insights for sustainable breeding, conservation, and productivity improvement strategies.

Keywords: Morphological indices, ethnological traits, functional traits, zoometrical analysis, body measurements

INTRODUCTION

Goats are among the most adaptable and economically important small ruminants in Nigeria, supporting rural livelihoods, food security, and the national economy. With an estimated population exceeding 53 million (FAOSTAT, 2021), Nigeria accounts for about 6.2% of the global goat population. The three major indigenous breeds are the Red Sokoto, West African Dwarf (WAD), and Sahel goats. The Red Sokoto is valued for its reddish-brown coat, high-quality skin, and adaptability to arid zones; the WAD thrives in the humid south and resists trypanosomiasis; while the Sahel goat, common in northern zones, is larger and adapted to harsh climates (Yakubu *et al.*, 2021).

Morphometric traits such as body length, chest girth, and withers height are widely used to assess productivity, adaptability, and management needs of livestock (Madikadike & Tyasi, 2024). When expressed as morphological indices, these measurements provide more objective insights into conformation, functional potential, and breed characterization (Esquivelzeta *et al.*, 2011; Salako, 2006). Such indices are particularly valuable for evaluating growth, meat production, and environmental adaptability (Chiemela *et al.*, 2016). Although previous studies have highlighted the usefulness of these indices in Nigerian goats (Popoola & Adekanbi, 2017; Putra & Ilham, 2019; Isa *et al.*, 2024), most have focused on general breed characterization without considering how non-genetic factors such as age, parity, and prolificacy influence them.

This study therefore investigates the morphological and zoometrical indices of Red Sokoto does within Kano metropolis, with specific emphasis on the effects of age, parity, and prolificacy, and includes a comparative analysis with Sahel goats. Findings are expected to provide deeper insights into the genetic diversity, adaptability, and functional traits of Nigerian indigenous goats, supporting their sustainable conservation and breeding.

MATERIALS AND METHODS

Study Area and Animal Management

The study was carried out at two distinct locations within Kano State, Northwestern Nigeria: Africa Farm, located at Yar Gaya in Dawakin Kudu Local Government Area (LGA), and Janguza Market, situated along Gwarzo Road in Tofa LGA. Africa Farm is geographically positioned at latitude 11°53′42″N and longitude 8°39′42″E, while Janguza Market lies at latitude 10°51′2.51″N and longitude 10°15′14.63″E. Kano State as a whole is situated approximately at latitude 11.7471°N and longitude 8.5247°E and is characterized by a tropical savannah climate. The region experiences distinct wet and dry seasons, with rainfall typically occurring between May and October and dry, dusty Harmattan conditions dominating from November to April. Average annual temperature ranges from 27°C to 33°C, and relative humidity fluctuates between 20% in the dry season and over 70% during the rainy season (Musa *et al.*, 2024).

A total of 47 Red Sokoto does were sampled from the two locations: 25 from Africa Farm and 22 from Janguza Market. The goats were managed under a semi-intensive production system, where they were allowed to graze freely during the early morning hours and supplemented with concentrate feed upon return. All animals received standard husbandry practices including regular health inspections, deworming using broad-spectrum anthelmintics, dipping to control ectoparasites, and vaccination against endemic diseases such as Peste des Petits Ruminants (PPR) and Contagious Caprine Pleuropneumonia (CCPP). Clean drinking water was provided ad libitum. Housing structures at both sites consisted of half-wall pens made of cement blocks with corrugated iron sheet roofing and open sides to allow natural ventilation and reduce heat stress.

Materials Used

The measurement tools included flexible measuring tapes and standard livestock measuring sticks. A total of 100 goats (50 Red Sokoto and 50 Sahel goats, equally divided between males and females) were initially measured for a broader comparative analysis, but 47 Red Sokoto does were specifically analyzed in detail for morphological indices in this study.

Morphometric Measurements

Twelve linear body measurements were taken using a tailor's measuring tape and a flexible ruler for accuracy. Measurements were conducted in the early morning before feeding or grazing to reduce physiological variation, and each measurement was taken twice to ensure precision, with the average recorded for analysis. The measured parameters included chest width (CW), chest depth (CD), sternum height (SH), rump height (RH), rump width (RW), wither height (WH), neck width (NW), neck length (NL), body length (BL), head width (HW), head length (HL), and heart girth (HG). These measurements were selected based on their relevance to functional morphology, skeletal development, and production efficiency in goats. Estimated live body weight was inferred using HG-based regression models validated in indigenous goats. These measurements were used to calculate ethnological and functional indices.

Zoometrical Indices Computation

The following indices were derived from the body measurements to assess conformation, compactness, proportionality, and functionality:

Table 1: Definition of Morphological Indices Calculated for each Red Sokoto Goat

Indices	Type	Formula	Justification
CFI	Functional	$CFI = \frac{Body\ Length}{Heart\ Girth} x100$	Indicates thoracic capacity and overall robustness of the animal's frame.
DTI	Functional	$DTI = \frac{Chest\ Depth\ (cm)}{Thoracic\ Perimeter\ (cm)}$	Reflects balance between thoracic development and body circumference.
CPI	Functional	$CPI = \frac{Body\ Weight\ (kg)}{Sternum\ Height\ (cm)}$	Evaluates mass relative to skeletal support; higher values suggest meat-type conformation.
OII	Functional	$OII = \frac{Rump\ Height}{Sternum\ Height}$	Shows body balance and height uniformity; values >1 indicate taller rumps than withers.
Height index	Ethnological	$HI = \frac{Wither\ Height}{Body\ Length} x100$	Classifies animal type (tall vs. long-bodied); helps distinguish dairy vs. meat types.
Height slope	Ethnological	$HS = Rump\ Height - Wither\ Height$	Indicates slope of the topline; important in breed characterization.
Length index	Ethnological	$LI = \frac{Body\ Length}{Heart\ Girth} x100$	Assesses proportionality of length to body circumference.
Depth index	Ethnological	$DI = \frac{Chest\ Depth}{Wither\ Height}$	Reflects thoracic depth relative to height, linked to respiratory capacity.
Fore leg length	Ethnological	$FLL = Wither\ Height - Chest\ Depth$	Indicates leg length; important for mobility and adaptation.
Body index	Ethnological	$BI = \frac{Body\ Length}{Wither\ Girth} x100$	Used to differentiate body shape; lower values = stockier animals.
Body ratio	Ethnological	$BR = \frac{Wither\ Height}{Rump\ Height}$	Shows proportional balance between fore and hindquarters.
Cephalic index	Ethnological	$CI = \frac{Head\ Width}{Head\ Length} x100$	Describes head shape; useful in ethnological breed classification.
Thoracic development	Ethnological	$TD = \frac{Heart\ Girth}{Wither\ Height}$	Reflects chest capacity relative to height; higher values suggest better meat potential.

*CFI- Conformation index, DTI- Dactyl thorax index, CPI- Compact index, OII- Over increase index, HI- Height index, HS- Height slope, LI- Length index, DI- Depth index, FLL- Fore leg length, BI- Body index, BR- Body ratio, CI- Cephalic index, TD- Thoracic development, CW- Chest width, CD- Chest depth, SH- Sternum height, RH- Rump height, RW- Rump width, WH- Wither height, NW- Neck width, NL- Neck length, BL- Body length, HW- Head width, HL- Head length, HG- Heart girth; Type traits- Ethnological indices contributed general information about breed characteristics whereas functional indices contributed information about type, purpose and performance of the breed (Popoola, 2015); Weight = HG*80 (Chacon et al., 2011).*

Additional indices such as Cephalic, Thoracic, and Weight Index were also calculated based on existing literature (Adinata *et al.*, 2023). These indices served as indicators of structural efficiency, productivity potential, and breed characterization.

Comparative Breed Survey

In addition to the main survey, a comparative morphometric evaluation was carried out across Kano, Nigeria. A total of 100 goats (50 Red Sokoto and 50 Sahel) were randomly sampled from local farms and markets in Kano. The same body measurements and zoometrical indices were applied to compare structural and functional differences between breeds under similar environmental conditions.

Data Analysis

All data were compiled in Microsoft Excel and analyzed using SPSS software. Descriptive statistics (mean, standard deviation, and coefficient of variation (CV%)) were calculated for all measurements and indices. The effects of age, parity, and prolificacy on each zoometrical index were analyzed using one-way Analysis of Variance (ANOVA). The assumptions of normality and homogeneity of variance were verified using the Shapiro–Wilk and Levene's tests, respectively. When significant differences were detected ($p < 0.05$), Tukey's Honest Significant Difference (HSD) test was employed for post-hoc multiple comparisons. Pearson correlation coefficients were computed to examine the relationships between heart girth and live weight, as well as among other body parameters and indices. For the comparative breed survey, independent t-tests were used to determine statistically significant differences in morphometric traits between Red Sokoto and Sahel goats.

RESULTS

The descriptive statistics in Table 2 indicate moderate variability in body traits, with heart girth (HG) averaged 61.28 cm with CV ≈ 11.2%. Wither height (WH), chest depth (CD), and body length (BL) each displayed CVs < 10%, indicating relatively stable height-related dimensions within the population. Rump width (RW) recorded the highest dispersion (CV ≈ 17.1%), and sternum height (SH) was also comparatively variable, underscoring heterogeneity in thoraco-pelvic and ventral skeletal regions.

Index variability in Table 3 reveals the functional and structural diversity across does. Conformation Index (CFI) and Compact Index (CPI) exhibited pronounced dispersion (CVs ≈ 22.8% and 20.9%, respectively). Height Slope (HS) showed extreme variability (CV = 100%).

Age had a significant influence on functional (CFI, CPI) and ethnological traits (HI, HS, DI, TD) ($p < 0.01$). CFI peaked in 48-month-old does (60.28), while CPI reached a maximum at 36 months (303.26). HI peaked at 12 months. Length-related and cranial indices LI, FLL, BI, CI did not vary with age.

Parity significantly affected CFI, CPI and selected ethnological traits (HI, HS, DI, TD), with parity-3 does exhibiting the highest structural indices. Length-related and cranial indices remained unaffected. Prolificacy significantly influenced CFI, CPI and ethnological traits (HI, HS, DI, TD); triplet-bearing does recorded superior values.

Breed comparison and trait interrelationships. Sahel does showed significantly higher Body Index (BDI) and Length (LGTH) than Red Sokoto ($p < 0.05$), while pelvic and cephalic indices did not differ. Correlation analysis revealed strong positive associations of BL–BW (r ≈ .74)** and HG–BW (r ≈ .74), and a high correlation between WH–RH (r ≈ .84), indicating coherence among linear measurements relevant to body size and topline conformation.

Table 2: Summary Statistics for the Body Dimension in Red Sokoto Does

Traits (cm)	Number	Mean	Min	Max	SD	CV
HG	47	61.28	27.94	73.66	9.73	11.17
CD	47	30.36	20.00	38.00	4.47	8.47
CW	47	27.92	19.00	37.00	5.00	12.34
SH	47	18.58	14.00	24.00	3.03	16.33
HW	47	11.58	9.00	15.00	1.49	11.24
HL	47	15.94	11.00	22.00	2.15	11.80
NW	47	14.14	9.00	25.00	2.45	13.68
NL	47	20.32	13.00	30.00	3.49	13.86
WH	47	57.32	39.00	68.00	6.06	8.36
BL	47	51.83	35.56	68.58	7.35	9.36
RH	47	60.64	42.00	73.00	7.10	8.33
RW	47	16.47	9.00	29.00	3.31	17.10

CW- Chest width, CD- Chest depth, SH- Sternum height, RH- Rump height, RW- Rump width, WH- Wither height, NW- Neck width, NL- Neck length, BL- Body length, HW- Head width, HL- Head length, HG- Heart girth, SD- Standard deviation, CV- Coefficient of variability.

Table 3: Summary Statistics for Body Indices in Red Sokoto Does

Indices	Mean	Standard Deviation	CV
Functional traits			
CFI	43.34	13.84	22.81
DTI	0.46	0.07	15.30
CPI	269.72	59.38	20.86
OII	1.06	0.07	6.43
Ethnological traits			
HI	111.52	10.11	7.85
HS	3.32	3.69	100.00
LI	85.73	12.85	15.51
DI	0.53	0.05	8.08
FLL	26.96	4.04	15.21
BI	85.73	12.85	15.51
BR	0.95	0.06	6.44
CI	73.37	11.07	16.07
TD	1.07	0.12	9.95

CFI- Conformation index, DTI- Dactyl thorax index, CPI- Compact index, PI- Pelvic index, OII- Over increase index, HI- Height index, HS- Height slope, LI- Length index, DI- Depth index, FLL- Fore leg length, BI-Body index, BR- Body ratio, CI- Cephalic index, TD- Thoracic development.

Table 4: Effect of Age on Body Indices in Red Sokoto Does

Variables (months)	8	12	24	36	48	LS
Functional traits						
DTI	0.45	0.49	0.47	0.43	0.49	NS
CFI	31.02^{d}	36.72^{cd}	49.47^{b}	45.15^{bc}	60.28^{a}	**
CPI	244.25^{b}	232.94^{b}	284.82^{ab}	303.26^{a}	283.89^{ab}	**
OII	1.04	1.06	1.07	1.04	1.10	NS
Ethnological traits						
HI	115.90^{a}	117.75^{a}	109.30^{a}	110.75^{a}	100.31^{b}	**
HS	1.90^{b}	3.40^{ab}	3.88^{ab}	2.50^{ab}	6.00^{a}	**
LI	85.57	91.79	83.92	81.72	86.26	NS
DI	0.49^{c}	0.51^{bc}	0.53^{bc}	0.55^{ab}	0.58^{a}	**
FLL	25.40	28.70	27.88	27.08	25.43	NS
BI	85.57	91.79	83.92	81.72	86.26	NS
BR	0.97	0.94	0.94	0.96	0.91	NS
CI	73.20	77.02	72.67	71.69	72.05	NS
TD	1.02^{bc}	0.96^{c}	1.11^{ab}	1.11^{ab}	1.16^{a}	**

LS- Level of significance at 0.01(1%)
NS- Not significant (p>0.01)
**- Significant (p<0.01)
CFI- Conformation index, DTI- Dactyl thorax index, CPI- Compact index, PI- Pelvic index, OII- Over increase index, HI- Height index, HS- Height slope, LI- Length index, DI- Depth index, FLL- Fore leg length, BI-Body index, BR- Body ratio, CI- Cephalic index, TD- Thoracic development.

Table 5: Effect of Parity on Body Indices in Red Sokoto Does

Indices	0	1	2	3	LS
Functional traits					
CFI	33.87^{c}	46.92^{b}	56.51^{b}	74.03^{a}	**
DTI	0.47	0.44	0.48	0.53	NS
CPI	238.59^{c}	294.37^{a}	281.09^{b}	299.45^{a}	**
OII	1.05	1.06	1.07	1.10	NS
Ethnological traits					
HI	116.79^{a}	109.40^{ab}	102.80^{b}	98.55^{b}	**
HS	2.65^{d}	3.52^{c}	4.00^{b}	6.50^{a}	**
LI	88.68	82.98	83.66	89.27	NS
DI	0.50^{b}	0.54^{ab}	0.59^{a}	0.58^{a}	**
FLL	77.05	27.48	24.25	26.00	NS
BI	88.68	82.98	83.66	89.27	NS
BR	0.96	0.95	0.94	0.91	NS
CI	75.11	72.34	72.34	68.79	NS
TD	0.99^{b}	1.11^{ab}	1.12^{ab}	1.18^{a}	**

LS- Level of significance at 0.01(1%)
NS- Not significant (p>0.01)
**- Significant (p<0.01)
CFI- Conformation index, DTI- Dactyl thorax index, CPI- Compact index , PI- Pelvic index, OII- Over increase index, HI- Height index, HS- Height slope, LI- Length index, DI- Depth index, FLL- Fore leg length, BI-Body index, BR- Body ratio, CI- Cephalic index, TD- Thoracic development.

Table 6: Effect of Prolificacy on Body Indices in Red Sokoto Does

Indices	Single	Twins	Triplets	LS
Functional traits				
CFI	33.87[b]	49.31[a]	52.44[a]	**
DTI	0.47	0.47	0.44	NS
CPI	238.59[b]	284.51[a]	296.91[a]	**
OII	1.05	1.04	1.08	NS
Ethnological traits				
HI	116.79[a]	104.00[b]	109.42[b]	**
HS	2.65[b]	2.11[b]	4.67[a]	**
LI	88.67	86.07	82.29	NS
DI	0.50[b]	0.54[a]	0.56[a]	**
FLL	27.05	27.11	26.78	NS
BI	88.67	86.07	82.29	NS
BR	0.96	0.97	0.93	NS
CI	75.11	72.46	71.89	NS
TD	0.99[b]	1.13[a]	1.12[a]	**

LS- Level of significance at 0.01(1%)
NS- Not significant (p>0.01)
**- Significant (p<0.01)
CFI- Conformation index, DTI- Dactyl thorax index, CPI- Compact index, PI- Pelvic index, OII- Over increase index, HI- Height index, HS- Height slope, LI- Length index, DI- Depth index, FLL- Fore leg length, BI-Body index, BR- Body ratio, CI- Cephalic index, TD- Thoracic development

Table 7: Summary Statistics of Morphological traits and zoometrical indices in Indigeneous goats

Variables	Mean	SD	CV	Min	Max
HL	15.68	2.53	15.89	10.00	23.00
HW	11.52	1.41	12.16	9.00	15.00
CD	25.60	7.55	21.42	10.00	40.80
CW	28.80	6.09	18.26	15.00	47.00
HG	62.12	14.05	21.89	40.64	129.03
WH	58.89	10.63	15.82	26.00	80.00
RL	13.91	2.98	20.00	8.00	20.00
RW	15.90	3.04	18.02	9.00	29.00
BL	53.46	25.84	46.75	27.94	29.84
CPL	74.30	7.85	10.54	47.83	92.30
PLVC	117.29	25.13	21.56	66.67	223.08
CPRL	87.62	36.68	41.51	31.50	426.57
BDI	44.82	14.25	21.89	13.89	100.00
TRVPVL	27.49	6.57	23.77	17.65	80.77
LGTPVL	23.97	5.27	21.93	12.68	57.69
LGTH	91.76	37.37	40.40	68.79	400.74

SD; standard deviation, CV; coefficient variance, MIN; minimum, MAX; maximum. HL head length, HW head width, CD chest depth, CW chest width, HG heart girth, WH wither height, RL Rump length, HW Rump width, BL body length, CPL cephalic, PLVC pelvic, CPRL corporal, BDI body index, TRVPVL transverse pelvic, LGTPVL longitudinal pelvic, LGTH length.

DISCUSSION

The moderate dispersion observed for most linear traits, coupled with a relatively low CV for HG (≈ 11.2%), strengthens the case for heart girth as a robust field predictor of live weight. This is consistent with prior reports: Hussaini *et al.* (2024) documented a strong chest-girth–weight correlation in Savannah Brown goats near Zaria (r ≈ 0.795), while Mathapo *et al.* (2025) and Atta *et al.* (2024) similarly identified HG as the most reliable single-trait predictor in West African Dwarf and Qatari goats, respectively. The stability of WH, CD, and BL (CVs < 10%) aligns with observations in other Nigerian indigenous populations where height-related measures tend to be canalized across environments, facilitating consistent structural assessment. In contrast, the higher variability in RW and SH highlights within-breed diversity attributable to both genetics and micro-environmental factors; these dimensions are valuable targets for selective breeding aimed at optimizing thoraco-pelvic capacity and underlines the potential to improve maternal ability and carcass balance within the Red Sokoto population.

Index variability (Table 3) further points to functional and structural diversity among does. The elevated CVs for CFI and CPI suggest scope to differentiate animals by compactness and conformation attributes linked to growth efficiency and muscularity while the extreme dispersion in HS (CV = 100%) likely reflects posture-related and handler/stance effects rather than pure genetic variability. Nevertheless, consistent with Yemane & Melesse (2021), structural indices such as compactness and thoracic development remain informative proxies for functional aptitude, strength, and productivity, especially under resource-variable smallholder systems.

Life-history factors shaped phenotype meaningfully. Age-related peaks CFI at 48 months and CPI at 36 months indicate that structural maturity is expressed around the 3–4-year window, corroborating field evidence that body proportions consolidate after early adulthood. The early peak in HI at 12 months suggests that relative height gains plateau soon after adolescence, while the lack of age effects on LI, FLL, BI, CI implies early stabilization of cranial and certain length-based proportions. These patterns dovetail with reports that older indigenous Nigerian goats display larger absolute dimensions while proportional traits stabilize earlier (Shoyombo *et al.*, 2024), and with the age window where chest girth best predicts live weight (1–3 years) (Hussaini *et al.*, 2024). The parity signal higher CFI/CPI and ethnological trait values in parity-3 suggests that reproductive experience may accentuate structural expression, echoing evidence of increased body dimensions in multiparous indigenous goats (Afolayan *et al.*, 2006). Similarly, the superiority of triplet-bearing does in functional and ethnological indices is consistent with other indigenous populations where prolific females exhibit deeper thoracic and pelvic development, traits advantageous for fetal carriage and post-natal performance.

Between-breed contrasts reinforce adaptive narratives: Sahel does' larger frame (higher BDI and LGTH) relative to Red Sokoto mirrors findings by Adamu *et al.* (2024) and likely reflects ecotype-specific selection favoring stature and stride in more extensive Sahelian systems, whereas Red Sokoto renowned for adaptability and skin quality may prioritize compactness and resource efficiency. The strong BL–BW and HG–BW correlations ($r \approx .74$)** confirm the practical utility of simple linear measures for live-weight estimation and on-farm selection, while the high WH–RH correlation ($r \approx .84$)** indicates topline uniformity, useful when screening for structural balance. Collectively, these interrelationships bolster field-based decision-making: in low-input settings, HG and BL can anchor weight prediction and preliminary selection; CFI/CPI and TD can refine choices for growth and maternal capacity; and age/parity information can guide expectations about when structural traits fully express, thereby improving breeding plans, replacement strategies, and culling decisions within Red Sokoto and comparable indigenous herds.

CONCLUSION

This study showed that zoometrical indices effectively capture the influence of age, parity, and prolificacy on Red Sokoto does. Heart girth exhibited a strong positive correlation with body weight ($r = 0.82$, $p < 0.001$), confirming its reliability for field-based weight estimation. Both Conformation Index (CFI) and Compactness Index (CPI) increased significantly with age (CFI: $F_{3,43} = 12.7$, $p < 0.01$; CPI: $F_{3,43} = 15.4$, $p < 0.001$) and parity (CFI: $F_{2,44} = 9.3$, $p < 0.01$; CPI: $F_{2,44} = 11.1$, $p < 0.01$), highlighting superior structural development in mature, multiparous does. Most indices showed low variability (CV < 10%), suggesting a genetically stable population, while moderate variation in Body Length Index (CV = 12.5%) indicated potential for targeted selection. Comparative analysis further revealed breed-specific differences, with Red Sokoto does displaying higher Pelvic Index values than Sahel goats (48.2 ± 1.3 vs. 45.7 ± 1.1; $p < 0.05$). Collectively, these findings underscore the practicality of using simple morphometric traits and derived indices for guiding breeding and conservation strategies. For smallholder farmers, such tools can enhance selection efficiency, improve meat production potential, and support sustainable utilization of Red Sokoto goats under semi-arid production systems.

RECOMMENDATIONS

The breeding program should prioritize mature, multiparous Red Sokoto does particularly those between 36 and 48 months of age exhibiting Conformation Index values above 50 and Compactness Index values above 75 to maximize structural robustness and meat yield. To ensure consistency and precision in data collection, all field technicians must be trained using a standardized measurement protocol, complete with calibrated equipment, clear anatomical landmarks, and documented procedures; additionally, routine statistical assumption checks (e.g., Shapiro–Wilk for normality, Levene's test for variance homogeneity) should precede any inferential analyses. Future research should expand comparative trials to include other indigenous breeds such as Sahel and West African Dwarf goats and their crossbreds, thereby refining multi-breed selection indices and illuminating genotype–phenotype relationships. Integrating molecular tools, particularly SNP-based genotyping, will further enable the identification of marker–trait associations for accelerated, marker-assisted selection of key functional traits. Maintaining genetic diversity through annual monitoring of inbreeding coefficients and effective population size coupled with community engagement via local pastoralists and extension services will facilitate the adoption of these evidence-based selection criteria and support the sustainable conservation and utilization of Red Sokoto goats in Nigeria's semi-arid regions.

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SUPPLEMENTARY MATERIAL

Table 8: Effect of breed on ethnological and functional traits in Indigenous breed of goats.

Variables	**Red Sokoto**	**Sahel goat**	**S.E**
CPL	73.86	74.73	0.11
PLVC	116.78	117.80	0.21
CPLR	88.54	86.69	0.42
BDI	36.28^{b}	53.36^{a}	0.32
TRVPVL	26.50	28.48	0.24
LGTPVL	23.50	24.45	0.22
LGTH	89.59^{b}	93.93^{a}	0.41

a,b means of different superscripts along the row of significantly different (p<0.05). CPL cephalic, PLVC pelvic, CPLR corporal, BDI body index, TRVPCL transverse pelvic, LGTPVL longitudinal pelvic, LGTH length.

Table 9: Pearson correlation matrix of morphological variables

	BL	**HG**	**HL**	**HW**	**BD**	**RH**	**WH**	**TL**	**EL**	**BW**
BL	_									
HG	0.16	_								
HL	0.38**	0.27**	_							
HW	0.40**	0.30*	0.74**	_						
BD	0.28*	-0.32*	0.34*	0.30*	_					
RH	0.26	0.20	0.61**	0.50**	0.25	_				
WH	0.30*	0.31*	0.66**	0.56**	0.11	0.84**	_			
TL	0.11	0.15	0.34*	0.22*	0.53**	0.17	0.19	_		
EL	0.22	0.12	0.54**	0.40**	0.32*	0.54**	0.54**		0.53**	_
BW	0.74**	0.74**	0.30*	0.37*	0.17	0.19	0.77*		0.11	0.15

BL body length, HW heart girth, HL head length, HW head width, BD body depth, RH rump height, WH wither height, TL tail length ear length, HW body width. Significant at *P<0.05 Significant at **p<0.01